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REVIEW OF DUST CONTROL AND ENGINEERING PARAMETERS IN PERCUSSION DRILLING

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REVIEW OF DUST CONTROL AND ENGINEERING PARAMETERS IN PERCUSSION DRILLING

by

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ABSTRACT

The mechanics of rock breakage, chip removal and dust control in percussion drilling is reviewed. The historical importance of wet drilling in dust control in underground operations is stressed as well as possible alternative dust control techniques.

Additional studies on clearing rock chips from under the cutting edges, especially with respect to wet flushing are recommended.

KEYWORDS: Percussion drilling, Percussion-rotary drilling, Dust control, Engineering parameters, Flushing-fluid flow-patterns.

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EXAMEN DU CONTRÔLE DE LA POUSSIÈRE ET DES PARAMÈTRES TECHNIQUES DU FORAGE PAR PERCUSSION

par

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RÉSUMÉ

La mécanique de la fragmentation des roches, de l'enlèvement des esquilles de roche et du contrôle de la poussière lors du forage par percussion est examinée dans le présent rapport. On y souligne particulièrement l'importance historique du forage humide pour contrôler la poussière dans les exploitations souterraines, ainsi qu'une technique possible de rechange pour effecteur le contrôle de la poussière.

Des études supplémentaires sur l'enlèvement des esquilles de roche des arêtes tranchantes, surtout lors du balayage humide, y sont recommandées également.

MOTS-CLÉS: Forage par percussion, forage rotary par percussion,
Contrôle de la poussière, Paramètres techniques,
Schémas d'écoulement du liquide de rinçage.

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INTRODUCTION

The incentive for this review of drilling is the need by the increasing number of mines using vertical bulk mining to drill long large down holes; up to 240 m long and 200 mm in diameter. The general industry belief is that the replacement of water by air as a flushing agent will reduce bit wear to the point where bit changes would not be required in one hole. This would give substantial savings. However, effective dust control is considered an essential requirement if air flushing is to replace wet drilling underground.

Improvement in drilling productivity related to bulk mining would seem to be an industry-wide need with substantial financial return if successfully addressed.

The industry's expectation that air will improve drill bit life is not supported by general experience with respect to the comparative life of rock cutting tools using water flushing. This suggests that the greater physical constraints imposed by drilling, as compared to rock cutting prevent effective flushing with water, that the presence of a relatively incompressible fluid increases which bit wear by cavitation and/or some other unidentified process is at work. It is also possible that compressed air flushing could be used beneficially with rock cutting tools.

The introduction of wet drilling in mines in the second quarter of this century was a major factor in the large reduction in the number of hard rock miners and tunnellers contracting silicosis and other pneumoconiotic diseases. The introduction of water flushing as a replacement for air flushing had the major disadvantage of reducing the penetration rate. As a result compressed air is still used as a flushing medium in many surface drilling operations where dust control is not critical. It is considered essential that good dust control be maintained in any drilling system used in an underground mine.

A search of the CANMET database MINTEC has located only a small number of articles relevant to this review. These have been included in the reference section(1,13).

For the purpose of this review, percussion drilling can be considered as a three stage operation:

1. Breaking chips from the solid rock.
2. Clearing chips and debris away from under the cutting edge prior to the next

blow.

3. Carrying chips and debris out of the drilled hole.

Three facets of percussion drilling must be taken into consideration in developing an effective dust control system: minimize generation of fine potentially airborne dust in the drilling breakage process and in the carriage of the broken fragments out of the hole; minimize dispersion of dust into the air by wetting as early as possible; and by collection or suppression of the airborne dust. Dust suppression can occur within the drillhole by adding water for that purpose or as the flushing agent, or air exiting from the drill hole by collection and filtration.

THE BREAKAGE PROCESS

The breakage process in percussion drilling has been described as consisting of pushing the cutting edge into the rock to cause crushing or plastic deformation of the immediate rock and the initiation of fractures. The cutting edge is then rotated (or advanced) and pressed in again; further crushing or plastic deformation and fracture initiation occurs and, if the rotation is correct, the fractures meet and a chip is raised from the rock. It is also possible that rotation with the bit pressed against the rock can cut rock and raise chips. Thus there are two possible percussive drilling cutting processes: first, percussion drilling where rotation simply assures application of the cutting edges to the entire face but where there is no significant application of rotary energy to the rock; and, second, percussive-rotary drilling in which percussion causes the cutting edge to enter the rock and the bit rotation is used to lift the chips(7).

Less energy consumption and fine dust generation per unit of rock occurs with large chip production. Apparently chip size production and energy input can be optimized taking into account the following drilling parameters: force per unit of cutting tool (length for inserts and some appropriate value for buttons), linear advance between blows and the sharpness of the cutting tool. Compromises have to be made, however, to meet the following practical constraints: tool life, tool strength, rotary motion and removal of chips and cutting debris from between the cutting edge and the rock. Cutting efficiency drops rapidly as debris builds up between the cutting edges and the rock. One function of the flushing process is to remove

this debris from the cutting region. It is also possible that the optimum sharpness profile of the cutting edge depends on drilling parameters such as the compressibility and viscosity, of the flushing fluid. There may be a large difference in optimum drill bit and use parameters resulting from the use of compressible and incompressible flushing fluids.

Additives to water have been shown to have an effect on rock breakage. It has been suggested that they can influence the crack propagation process. Work on rock cutting tools suggests, however, that the penetration rate of active agent into the rock is an order of magnitude too slow to influence cutting action when the rock cannot be prewetted(11).

CLEARING DEBRIS FROM THE CUTTING REGION

As mentioned previously debris in the cutting region reduces cutting efficiency. The main reason for this is that it cushions the impact on the rock and wastes energy in further breakage. Effective chip removal ready for cutting requires that the the flushing fluid clears the cutting surface of all chips between impacts. The efficient removal of the chips requires careful attention to the pattern of fluid flow throughout the cutting region and the paths for the large chips to clear the bit head and enter the drill hole. A sufficient fluid velocity must be present to lift and transport the chips(2,14).

The flushing fluid flow pattern will depend on the compressibility and density of the flushing fluid. There will also be differences between air and water flow patterns because of compressibility and viscosity effects. The pumping action of the drill on an incompressible fluid could significantly modify the flow pattern and chip removal. With such fluids the upstroke of the bit could be accompanied by cavitation. This could have a significant influence on the chip raising and removal processes as well as on tool wear.Because of the difference between soft and hard rocks in penetration rates and debris removal requirements, flushing fluid and flow pattern requirements differ.

Clemmow's study of the flow pattern in conventional crossbits with compressed air flushing has shown that penetration rates can be doubled with improved bits (2).

REMOVAL OF CHIPS FROM THE DRILL HOLE

The failure to remove chips from a drill hole can cause unnecessary energy loss as well as jamming of the drill bits and rods in the hole. Chip removal is most difficult in down holes because of gravity. The second main function of the flushing fluid is the transport of chips out of the drillhole. It has been shown that a minimum velocity exists for chip transport upwards dependent on chip size, chip density, gravitational force, fluid density and fluid viscosity(14).

The standard drilling process involves chip transport up the annulus between the drill rod and the outside of the hole, and flushing fluid transport down a central passage. The passage sizes and flows must be selected to achieve balance

A third function of the flushing fluid is to provide the pressure and density sometimes required to prevent drill hole wall collapse. However, this is probably not relevant to underground production drilling in mines, and is not considered further in this report.

DUST CONTROL

A number of factors and related actions can be considered to achieve better dust control in percussive rock drilling:

1. Minimizing dust generation–specific dust generation is closely related to specific energy consumption in drilling. The larger the chips produced the smaller is the specific energy consumption and the specific generation of fine potentially airborne dust. Thus improvements in drilling efficiency can be expected to also reduce dust generation.
2. Preventing dust dispersion–the use of a liquid flushing agent prevents contact with air and thus can be an extremely effective method of dust control. Major dust emissions are believed to occur only when the compressed air raises a mist by leakage into the flushing water or by some other means.
3. Introduction of water into the flushing air–this does provide some reduction in dust emissions but plain water is not very effective (12).

4. Drill stem water separation is a technique which offers the advantages of compressed air flushing without the disadvantages of water under the drill bit. In this an inertial water separator is used and the water sprayed into the drill hole above the drill(15). Larger quantities of water can be used than in item 3. above to give more effective dust control. Dust control is not expected to be as effective as wet flushing, especially in short holes. It may be desirable, for dust control, to drill the first drill steel length without using the separator.

5. Introduction of foam into the flushing air has been shown to be effective (12,13).

6. Filtration of air leaving the drill hole– The air leaving the drill hole is under a slight pressure. This permits the use of a non-powered filter for dust collection. While the filter can be effective in removing dust from air passing through it, the main source of dust emission is leakage around the joints between the dust collector hood and the rock face or drill. These seals are difficult to maintain.

7. Assisted filtration–leakage through the seals can be prevented by using an air mover, such as a fan or venturi, to move a larger volume of air through the filter than is coming out of the drill hole.

8. Filter type –both dry and wet type filters can be used. With dry type filters the dust is bagged to prevent later dispersion into the air. With wet type filters it is usual to drop the slurry on the floor. This treatment is suitable in low traffic areas.

9. Dilution ventilation is seldom suitable because of the large quantities of dust produced in dry drilling operations.

10. Directional control of ventilation could be used if the layout is suitable. This requires that the operators be kept on the upwind side of the drill and that the air can be passed to and through a return airway without passing any personnel.

For the particular problem of using air flushing underground on large drills the most promising approaches are drill stem water separation, foam and assisted filtration with a wet scrubber. Foam has been examined for this purpose and the requirements established by (12,13). It appears that the amount of foaming agent required would be enough to make the entire flushing airflow a thin foam at the exit from the drill hole. A venturi scrubber using

water sprays as dust control on the inlet and air mover or with a compressed air coanda supplementary air mover should be considered as an alternative to a fan and dry filter with bags for dust disposal.

RESEARCH APPROACHES

1. Short term approach–use existing equipment and study their dust suppression capabilities.
    a. Commercial venturi dust scrubbers.
    b. Drill stem water separation.
    c. Foam dust suppressants.
    d. Commercial dry filters with bag disposal.
2. Long term approach–study drilling and clearance parameters with air and water flushing.
    a. Model studies on fluid flow under the drill bit with various placements of flushing jets and sludge grooves.
    b. Construction of experimental or modified bits.
    c. Experimental studies with improved bits at shallow depths.
    d. Experimental studies with improved bits at depth.

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